SECTION II.—GENERAL METEOROLOGY.

CLOUDS AND THEIR SIGNIFICANCE IN LOCAL WEATHER FORECASTING.

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[Dated: Weather Bureau, San Francisco, Cal., Aug. 15, 1918.]

The significance of clouds in weather forecasting has been tested by various investigators. In general, it has been found that when clouds are considered without regard to their direction of movement or velocity of motion little information regarding the subsequent weather is indicated. When the direction from which they move and their velocity are considered, however, the significance of clouds in weather forecasting is of considerable importance in a region of cyclonic control. Particularly is this true on the Pacific coast of the United States, where, because of the impossibility of securing current data from the vast expanse of ocean to the west, every suggestive bit of information concerning the movement of cyclones is desired. Moreover, it is the writer's opinion, based upon various periods of residence in widely separated portions of the country, that everywhere within the United States the best opportunity offered the local forecaster successfully to amplify and to improve upon the district forecast is found in careful observation and interpretation of the local clouds, as a supplement to what will always be the more important guide—namely, the barometric distribution, with the recent changes in pressure.

In order to test the significance of clouds in weather forecasting and to determine the probability of precipitation and temperature changes following the various kinds of clouds at San Francisco, nine years of records, those of 1906 to 1915, have been examined. The data serving as the basis for this study are selective in the following respects: (1) Only data for the winter half year, November–April, inclusive, have been used. (2) Only the cloud observations taken as a part of the regular evening observations have been examined with respect to the subsequent weather. The necessity for thus limiting the data will be made evident from the following statement of facts:

San Francisco (latitude 37° 48′ N., longitude 122° 23′ W.) is situated upon a peninsula 7 miles in width, south of the entrance to, and west of the main portion of, a large bay of the same name. It is on a coast which runs northwest to southeast. Its mean annual temperature is 54.9°, and its mean annual precipitation is 22.27 inches. It is subject to a marine régime in climate, with small diurnal and annual ranges in temperature. Located on the northern border of the "horse latitudes," it receives about 91 per cent of its precipitation during the six months November–April, inclusive. During the nine years forming the basis of this study, 34 per cent, or practically one-third of the days during the winter half-year were rainy days—that is, days with 0.01 inch or more of precipitation. Snow rarely occurs, there being but three instances of snowfall during the nine years, and the greatest amount during that period measured but 0.04 inch in water when melted. The cyclonic control is dominant during the winter only. As the regular observations are taken at 4:50 a. m. and 4:50 p. m., local mean solar time, the morning observations are usually taken in the darkness of night during the winter, rendering the cloud observations at that hour so difficult, and subjecting them to such large probabilities of error, that they can not safely be used in any critical study. Though based principally upon San Francisco data, the conclusions are doubtless applicable throughout all that portion of the United States subject to cyclonic control of the weather, and that includes the greater portion of the country.

CIRRUS AND CIRRO-STRATUS CLOUDS.

The highest clouds are of the cirrus and cirro-stratus type. During the international "cloud-year," 1896–97, special cloud observations were taken throughout the civilized world. At the Central Office of the Weather Bureau in Washington a total of 3,978 observations of clouds were taken during that year. In this series the average height of cirrus clouds during winter was found to be 9.51 kilometers (31,200 feet, or approximately 6 miles), while that for cirro-stratus clouds was 9.53 kilometers (31,300 feet, or approximately 6 miles). Washington and San Francisco are in practically the same latitude, and it is probable that the general characteristics of clouds are similar in the two places during the winter half-year. The maximum height at which either kind of cloud was observed was 16.46 kilometers (54,000 feet, or approximately 10 miles), while the minimum height was 4.93 kilometers (16,200 feet, or approximately 3 miles). It is apparent from these figures that cirrus and cirro-stratus clouds are found only at high levels, so high, in fact, that they are above the lower limit of permanent freezing temperatures. The particles composing the clouds are usually, if not always, solid, often in the form of hexagonal prisms of ice.

In velocity the average for all cirrus clouds measured was 35 meters per second (78.3 miles per hour), while that for cirro-stratus cloud was 30 meters per second (67.1 miles per hour). The most rapidly moving cirrus clouds were traveling at a rate of 80 meters per second (179 miles per hour). As indicated by these figures, cirrus and cirro-stratus clouds usually show rapid movement. When any clouds are moving with unusual rapidity observers in the Weather Bureau are expected to include in their telegrams an indication of this fact. On account of the great height the velocity of clouds of this type is often underestimated by observers, and, as a result, they are seldom reported as moving with more than ordinary rapidity. It should be remembered that on account of the height of these clouds any apparent motion at all is an indication of considerable movement, and where the apparent motion is easily perceptible the actual movement is proportionately high. With the possible exception of certain mountain regions there is, on the average, a more or less uniform increase in the wind velocity with height throughout the United States, up to the levels of the highest clouds. During most of the time this is true regardless of the presence or absence of clouds.

Though cirrus and cirro-stratus clouds are apparently at times associated with anticyclones, they are typical

accompaniments of cyclones. If a longitudinal section were made through the vertical axis of a typical cyclone, and parallel to its direction of progression, the cirrus and cirro-stratus sheet forming the topmost portion would extend forward from the center a long distance, and backward a shorter distance. In the sequence of events which usually precede cyclonic precipitation, clouds of this kind are ordinarily the first sign, often occurring many hours before the barometer begins to fall, or before any other indication of the coming storm makes its appearance. The significance of the fringe of cirrus and cirro-stratus clouds surrounding the cyclone is often the object of inquiry among mariners, to whom a storm is often of great concern.

Table 1 is a summary of the weather conditions following cirrus and cirro-stratus clouds observed at San Francisco during the nine years, with the limitations outlined above. All cirrus and cirro-stratus clouds covering 0.1 or more of the sky at the time of the observation are included in the table, which embraces 359 cases. The weather following is computed in terms of the per cent of frequency of occurrence, and is given for all directions where the cases number five or more. Before discussing the table in detail attention should be called to one fact. High clouds can necessarily be observed only when not obscured by lower clouds. If it were possible to include data of these clouds even when they are obscured by lower clouds it is not unlikely that their significance would be enhanced.

TABLE 1.—*Weather conditions following cirrus and cirro-stratus clouds.*

Clouds moved from—	Number of cases.	Precipitation followed.		Temperature changed within 24 hours.		
		Within 24 hours.	Within 36 hours.	Less than 4°.	4° or more warmer.	4° or more colder.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent*	*Per cent.*
N.	14	7	7	72	14	14
NE.	12	0	8	84	8	8
E.	1	.....	.....	.....	.....	.....
SE.	0	.....	.....	.....	.....	.....
S.	7	29	29	100	0	0
SW.	48	31	40	60	10	30
W.	132	20	27	60	17	23
NW.	116	12	22	73	12	15
Calm.	29	10	28	66	17	17

As is indicated in Table 1, cirrus and cirro-stratus clouds moving from some direction in the southwest quadrant of the compass are far more indicative of precipitation than are those from any other quadrant. Moreover, clouds of this type which show no apparent motion have a high degree of probability in forecasting precipitation, though the rainfall may be long delayed. In general, it may be said that clouds showing a relatively high velocity indicate that the movement of the storm is relatively fast, and vice versa. This fact influences the time of the beginning as well as the time of the ending of the rainfall following. Though not shown in the table, the observations also indicate that when the winds aloft, as shown by the movement of the higher clouds are from a southwesterly direction and relatively high in velocity, high southerly winds may be expected at the surface in 4 to 12 hours. What is known as windy cirrus (cirrus ventosus), a cirrus cloud of much tangled fibers, is indicative of violent convection. In San Francisco high velocities aloft are not communicated to the surface stratum when they are from any quadrant other than southwest. However, this is probably a local condition, as observations in other parts of the United States show that the high northwest winds usually found at the rear of a typical winter cyclone are generally heralded by swiftly moving cirrus and cirro-stratus clouds from a northwesterly direction. Moreover, there is little or no relation apparent between the direction from which cirrus clouds move and the total amount of precipitation following. While discussing the direction of movement of these clouds attention should be called to the relatively small number of cases of those moving from an easterly point. Of the 359 cases of cirrus and cirro-stratus clouds observed, only 13 cases, or less than 4 per cent of the total, were found of clouds of this type crossing the meridian from an easterly point. In view of this fact it behooves observers to take special care in reporting clouds of this kind as moving from an easterly direction. When instances of this nature are encountered accuracy demands that additional observations be taken in order that no mistake be made.

As far as temperature changes are concerned, cirrus and cirro-stratus clouds were found to have little significance at San Francisco. Because of its semimarine environment marked temperature changes during a period of 24 hours are uncommon. Adopting arbitrarily a change of four degrees as a tenperature change, it was found that when all cirrus and cirro-stratus clouds were included regardless of direction of movement, two-thirds of the cases were followed by no temperature change within 24 hours. Of the several directions, however, cirrus and cirro-stratus clouds moving from the west or southwest were most frequently followed by a temperature change. When, following cirrus or cirro-stratus clouds from any direction, the change occurred within 24 hours, it was more often negative than positive.

Another word of caution regarding the observation of clouds may properly be interpolated at this point. Great care should be exercised by the observer to avoid confusing a developing or a vanishing filament of cloud with the true movement of the cloud itself. When cirrus clouds take the form of long bands or streamers radiating from a distant focal point, the cloud proper may be moving in the direction toward which the streamers point, but not necessarily so. When such a point of convergence is followed by a stratiform cloud which becomes lower and lower as it progresses, and the barometer shows an unquestioned downward tendency, it may safely be concluded that a cyclonic storm is following. On the other hand, if such a focal point is followed by broken cloud, and perhaps blue sky, fair weather is indicated. This suggests a point which the forecaster can not overestimate in importance. Cloud observations can not alone serve as a basis of forecasting. But when considered in conjunction with the various other phenomena which usually herald the approach of a cyclone they are a contributory factor which can not be neglected. Most weather changes occur in cycles. An experienced meteorologist is able to determine the various stages in this sequence of events. Moreover, a careful observer is able not only to recognize the genus of cloud, but further to differentiate each genus into its several species.

At San Francisco, as well as elsewhere in the United States, it is comparatively easy to distinguish between various species of cirrus clouds, and to designate which are most frequently followed by weather changes, and which are not. Cirrus clouds exhibit such great variety in appearance as well as in structure that the conditions which produce and sustain them must be of many different kinds. Photography has shown that true cirrus and

cirro stratus clouds are always fibrous in structure, though this is not always apparent to the naked eye. Furthermore, when clouds of this type exist at two or more different levels, often traveling in different directions, it is a sign of unstable conditions aloft, and is usually followed by unsettled weather. Always high in the atmosphere, cirrus and cirro-stratus clouds present a rudy afterglow, thus prolonging the twilight.

Other facts affecting the significance of these clouds are worthy of note. Cirro-stratus cloud is more often followed by precipitation than is cirrus, largely because it marks a later stage in the sequence of events of cyclonic origin. Moreover, solar and lunar halos obtain their significance as weather signs because they are always formed in clouds of this type. The particular species of cloud in which they form has aptly been termed cirro-nebula (cirrus-veil). Though a stratiform cloud, it is much attenuated, and produces the most conspicuous halos when it is itself almost invisible, and gives the sky a faint, milk-white appearance. Partly because of the low temperatures prevailing in the plane of cirrus and cirro-stratus clouds, the actual amount of water carried in suspension in these clouds is never large, and can never produce a measurable amount of precipitation at the ground. Though wisps of falling ice crystals may often be observed at the rear of swiftly moving cirrus clouds, they never give measurable precipitation. Again, because of the low temperature the vapor condensed to form clouds of this type passes directly from the gaseous state to the solid form, thus explaining the crystalline structure of the constituent particles, and the fact that the prismatic colors of the halos are always arranged with the red on the inside. In general, cirrus and cirro-stratus clouds are somewhat higher in summer than in winter, while they move with a considerably higher average velocity in winter than they do during the summer half year.

CIRRO-CUMULUS CLOUDS.

Cirrus and cirro-stratus clouds are ordinarily considered as one and the same type of cloud, since they exhibit similar characteristics, and the one is simply a stratiform type of the other. Cirro-cumulus clouds, however, are somewhat different, and properly form a class by themselves. Often giving rise to what is popularly called a "mackerel sky," they form the basis of many weather proverbs. When visible in the late afternoon and evening they contribute largely to the brilliancy of sunset, and help to prolong the twilight.

The average height in winter of cirro-cumulus clouds as determined from the Washington observations was 7.41 kilometers (24,300 feet, or approximately 4½ miles). The highest clouds of this type were found at 15.41 kilometers (50,600 feet, or approximately 9½ miles), while the lowest were at a level of 3.07 kilometers (10,010 feet, or approximately 2 miles). It is thus apparent that cirro-cumulus, like cirrus and cirro-stratus, are high-level clouds, so high that the visible particles constituting the cloud are usually, if not always, in the solid state. As they are found only at levels above that of permanent freezing temperature, the water must have passed directly from the gaseous to the solid state. Though considerably lower in average height, cirro-cumulus clouds were found to have about the same average velocity as that of cirrus and cirro-stratus clouds, namely, 33 meters per second (73.8 miles per hour).

TABLE 2.—*Weather conditions following cirro-cumulus clouds.*

Clouds moved from—	Number of cases.	Precipitation followed.		Temperature changed within 24 hours.		
		Within 24 hours.	Within 36 hours.	Less than 4°.	4° or more warmer.	4° or more colder.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
N.	2	.....	.....	.....	.....	.....
NE.	0	.....	.....	.....	.....	.....
E.	0	.....	.....	.....	.....	.....
SE.	3	.....	.....	.....	.....	.....
S.	0	.....	.....	.....	.....	.....
SW.	14	36	50	64	7	29
W.	19	42	53	58	21	21
NW.	21	19	29	72	14	14
Calm.	3	.....	.....	.....	.....	.....

Table 2 is a summary of the weather conditions following 62 cases of cirro-cumulus clouds observed at San Francisco during the nine years. When classified as to direction of movement it was found that one-half of the instances of cirro-cumulus clouds from the southwest were followed by precipitation within 36 hours, while more than one-half of those moving from the west were followed by rain within that period of time. Those moving from the northwest were followed by rain but 29 per cent of the time. Cirro-cumulus clouds showing no apparent movement, or moving from any direction other than from those mentioned, were infrequent. It appears that weather proverbs which state that rain is likely to follow a "mackerel sky" have considerable basis in fact, provided that the clouds are moving from the west or southwest.

Temperature changes follow cirro-cumulus clouds more frequently than they do cirrus or cirro-stratus clouds. Cirro-cumulus clouds moving from the west were followed by temperature changes almost one-half of the time, being as often positive as negative. Those moving from the southwest were followed by negative changes far more frequently than by positive changes.

Certain other facts observed in connection with cirro-cumulus clouds are noteworthy. Clouds of this type are of infrequent occurrence, and are never long-continued, suggesting that the causes which give rise to them are relatively feeble and short lived. Their cumulus form indicates that vertical convection must play an important part in their formation. On account of their height, however, currents ascending from the ground can not explain their origin. Moreover, the rapid horizontal movement of the air at these levels does not allow vertical convection to persist long. Vertical movements resulting from friction between adjoining strata of air moving in different directions, or at different rates, perhaps play a part in the cause of their formation. Helmholtzian waves may give rise to simple, parallel rows of cloud, or to complex arrangements when two adjacent air currents have different velocities. In general, it may be said that cirro-cumulus clouds are a sign of unstable conditions aloft, and are therefore a reasonably good sign of coming weather changes. In the usual sequence of events preceding cyclonic precipitation they mark an intermediate stage, being preceded by the higher cirrus and cirro-stratus clouds, and followed, or rather obscured, by the lower alto-cumulus and alto-stratus clouds. The sequence is in the reverse order and accelerated in time in the events following cyclonic rainfall.

ALTO-CUMULUS CLOUDS.

The Washington observations showed the alto-cumulus clouds to have an average height in winter of 3.82 kilometers (12,500 feet, or approximately 2½ miles). The highest observed were found at 10.17 kilometers (33,400 feet, or approximately 6½ miles), while the lowest were at 1.52 kilometers (5,000 feet, or approximately 1 mile). The average velocity of movement was determined to be 21 meters per second (47 miles per hour), though one observation showed a cloud to be moving at the rate of 54 meters per second (120.8 miles per hour).

Alto-cumulus is thus found at intermediate cloud levels. Though sometimes above and sometimes below the isotherm of freezing in the free air, its constituent water particles are usually, if not always, in the liquid form, as is evidenced by the following:

Optical phenomena like coronas, resulting from the passage of rays of light through thin alto-cumulus or alto-stratus clouds, have their spectrum colors arranged with the red on the outside, a fact possible with liquid particles only. Moreover, alto-cumulus and alto-stratus clouds do not ordinarily show a fibrous structure, while cirriform clouds always do. These statements are important in view of the fact that the liquid form of the individual particles is retained though they sometimes float in air well below the freezing point in temperature. Though the individual droplets thus exist in a liquid state at subfreezing temperatures, two or more droplets coming into contact may coalesce and take the solid form. If this process continues long enough the cumulus appearance is replaced by that of the stratiform type.

Table 3 is a summary of the weather conditions which followed 95 cases of alto-cumulus clouds observed at San Francisco during the period under consideration. It is apparent from the table that clouds of this kind moving from directions north to southeast, inclusive, are uncommon. Alto-cumulus clouds moving from any direction except northwest, or showing no apparent movement, were followed by rain within 36 hours at least one-half of the time. Those moving from the south were followed by rain three out of every five times.

TABLE 3.—*Weather conditions following alto-cumulus clouds.*

Clouds moved from—	Number of cases.	Precipitation followed.		Temperature changed within 24 hours.		
		Within 24 hours.	Within 36 hours.	Less than 4°.	4° or more warmer.	4° or more colder.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
N	1	.....	.....	.....	.....	.....
NE	1	.....	.....	.....	.....	.....
E	0	.....	.....	.....	.....	.....
SE	1	.....	.....	.....	.....	.....
S	5	60	60	80	0	20
SW	20	40	50	75	10	15
W	35	34	51	74	12	14
NW	22	32	41	77	14	9
Calm	10	50	50	80	0	20

The cumulus structure of this type of cloud suggests that ascending currents play an important part in causing its formation. It is a well-recognized fact that condensation resulting from ascending currents is far more likely to result in precipitation than is condensation, which results from the mixing of air masses differing in temperature or in humidity. This principle explains why clouds of the cumulus type often precede torrential rains of brief duration, while stratus clouds and fogs may persist for days without producing measurable precipitation. For this reason alto-cumulus clouds are of greater significance to the forecaster than are alto-stratus clouds of the same level.

The alto-cumulus cloud makes visible the fact that a cloud is never in a state of equilibrium. Within every cloud evaporation and condensation are constantly going on, and the particles making up the visible cloud mass are constantly forming and vanishing. A cloud diffuses solar light and heat so effectively that a body inclosed within it is subjected to light and heat radiation from all sides. When a thermograph is carried through a cloud stratum by a kite or a balloon, a wave-crest is almost invariably formed in the thermogram.

ALTO-STRATUS CLOUDS.

The average height of alto-stratus clouds during winter, as determined by the Washington observations, was 4.80 kilometers (15,000 feet, or approximately 3 miles). The average velocity, based upon observations for all seasons, was 21 meters per second (47 miles per hour).

As indicated by its name, alto-stratus is a high stratiform cloud. Though not so high as cirro-stratus, it is usually much thicker, and, unlike the latter, it frequently is the source of considerable precipitation. Its constituent particles are usually in the liquid form, though the temperatures are often below freezing. It does not usually show a fibrous structure, either to the naked eye or to the photographic plate. When a luminary like the sun or the moon is observed through thin alto-stratus cloud a corona, with the red end of the spectrum on the outside, is apparent. In the usual sequence of events between the appearance of the first cirrus streamers and precipitation it marks an intermediate stage, most frequently following alto-cumulus and immediately preceding the lower clouds which give the precipitation. If a map were drawn to show the prevailing cloud visible in all parts of a typical cyclone, alto-stratus cloud would form a broad ring nearly concentric with the isobars, and immediately surrounding the area where rain was falling. This ring would be broad at the front and narrow at the rear.

Table 4 is a summary of the weather conditions which followed the observation of 156 cases of alto-stratus clouds at San Francisco during the nine years. The relative infrequency of this kind of cloud moving from north to southeast, inclusive, indicates that the indraught in the immediate front of a cyclone does not ordinarily reach to alto-stratus levels. Moreover, the probability of rain following the appearance of this kind of cloud is considerable. It is greatest for clouds moving from south or southwest, those from these directions having been followed by rain more than one-half of the time. The probability of rain decreases as the direction from which the clouds move approaches north. Furthermore, the rain is far more likely to occur during the 24-hour period immediately following the observation of the cloud than it is during the subsequent 12-hour period. Though not indicated in the table, it was observed that the amount of precipitation received after the appearance of these clouds moving from the south or southwest was usually heavy, a half inch or more of rain within 24 hours having been considered heavy. Those moving from any other direction were followed by rains only light or moderate in amount.

TABLE 4.—*Weather conditions following alto-stratus clouds.*

Clouds moved from—	Number of cases.	Precipitation followed.		Temperature changed within 24 hours.		
		Within 24 hours.	Within 36 hours.	Less than 4°.	4° or more warmer.	4° or more colder.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
N.	1	.....	.....	.....	.....	.....
NE.	1	.....	.....	.....	.....	.....
E.	2	.....	.....	.....	.....	.....
SE.	3	.....	.....	.....	.....	.....
S.	10	60	60	70	0	30
SW.	34	50	56	75	6	19
W.	55	33	44	76	13	11
NW.	34	24	32	94	3	3
Calm.	16	44	44	57	12	31

The significance of alto-stratus clouds regarding subsequent temperature changes is worthy of attention, particularly of those clouds showing no apparent movement, which were followed by temperature changes almost one-half of the time. These changes were far more frequently negative than positive.

Certain other considerations associated with alto-stratus clouds present themselves. Measurable amounts of precipitation do not ordinarily occur from these clouds unless they are of considerable thickness, sufficient at least to render invisible the sun or the moon, if either is above the horizon. Moreover, the density as well as the actual amount of water carried in suspension in alto-stratus clouds is considerably greater than that of the higher cirro-stratus clouds. Furthermore, the amount of water condensed and precipitated by the former is greater than that of the latter. These facts are directly dependent upon the difference in temperature between the two levels. A fall in temperature from 65° to 60° in an alto stratus cloud will give a vastly greater amount of condensation and precipitation than will a fall from 25° to 20° in a cirro-stratus cloud. Again, following the precipitation near a cyclone center, more rain may be expected as long as the alto-stratus cloud remains unbroken. When, however, the latter shows distinct breaks, without a higher cloud stratum above, no more long-continued rain may be expected from that particular cyclone.

CUMULUS CLOUDS.

The average height in winter of the tops of cumulus clouds observed in Washington was 2.28 kilometers (7,500 feet, or approximately 1½ miles), while that for the base was 1.20 kilometers (3,900 feet, or approximately ¾ mile). The tops varied greatly in level, however, taking the year as a whole. One observation showed the top of a cumulus cloud to reach a level of 6.76 kilometers (22,200 feet, or approximately 4 miles), while on another occasion it reached only 0.91 kilometer (3,000 feet, or approximately ½ mile). The average velocity of the summits was found to be 11 meters per second (24.6 miles per hour).

True cumulus clouds are more often associated with the borders of a cyclone than with its center. Usually of local formation, their vertical dimensions often exceed their horizontal. Along the immediate coast of California this type of cloud is most frequently observed during the winter months, since the strong though superficial winds of summer then render their formation impossible. Throughout the remainder of the United States, cumulus, together with strato-cumulus, are typical summer clouds, partly because the strong winds of winter prevent local heating and the ascending currents necessary to produce them. At San Francisco cumulus clouds do not often develop into cumulo-nimbus clouds, as is shown by the fact that only one thunderstorm occurs each year, on the average, and it is usually mild. In certain places within the Tropics cumulus clouds are a daily occurrence, due partly to excessive local heating and partly to the absence of strong horizontal movement. Wherever observed, cumulus clouds are of particular interest because of the information they give concerning the wind velocity aloft. Though the base of a cumulus cloud is ordinarily found in a region of comparatively calm air, the summit of the cloud often extends into a region of swiftly moving air. Under these conditions the cloud leans forward. Sometimes the increase in wind velocity with increase of height is so rapid that the cloud "loses its head"; that is, the top portion is detached from and is blown in advance of its base.

TABLE 5.—*Weather conditions following cumulus clouds.*

Clouds moved from—	Number of cases.	Precipitation followed.		Temperature changed within 24 hours.		
		Within 24 hours.	Within 36 hours.	Less than 4°.	4° or more warmer.	4° or more colder.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
N.	1	.....	.....	.....	.....	.....
NE.	2	.....	.....	.....	.....	.....
E.	0	.....	.....	.....	.....	.....
SE.	1	.....	.....	.....	.....	.....
S.	4	.....	.....	.....	.....	.....
SW.	33	52	58	79	15	6
NW.	10	30	60	80	10	10
Calm.	1	.....	.....	.....	.....	.....

Table 5 is a summary of the weather conditions following the observation of 52 cases of cumulus clouds observed at San Francisco. That they are not a common type of cloud is suggested by the fact that they were visible at the time of the evening observation but 52 times in the 9-year period. On these occasions, 83 per cent of them moved from the west or northwest. Their significance in regard to subsequent precipitation is great, as is evidenced by the fact that 58 per cent of those moving from the west and 60 per cent of those moving from the northwest were followed by rain within 36 hours. The rain is not long delayed in following these clouds, and usually consists in sporadic showers, irregularly distributed.

The significance of these clouds regarding temperature changes is not great, only about 20 per cent being followed by such changes within 24 hours.

STRATO-CUMULUS CLOUDS.

The Washington observations showed the strato-cumulus clouds to have an average height in winter of 2.40 kilometers (7,900 feet, or approximately 1½ miles). Their average velocity was 15 meters per second (33.6 miles per hour). That they are associated with more unstable conditions than are cumulus clouds is suggested by the fact that their average velocity is almost 40 per cent greater. One computation indicated a strato-cumulus cloud to have a velocity of 33 meters per second (73.8 miles per hour).

Just as cirrus and cirro-stratus are the most common of the high-level clouds, so, at San Francisco, strato-cumulus are the most frequently observed low-level clouds. This is probably true wherever cyclones control the weather. In variety of appearance, strato-cumulus

is exceeded only by cirrus. Formed only at low levels, its constituent particles are usually in liquid form, though the combination of two or more particles may produce snowflakes, when the temperatures are sufficiently low. Of itself, this kind of cloud does not give heavy nor wide-spread precipitation. Throughout most of the United States it gives only light showers in summer, and snow flurries in winter. However, it is closely associated with the true nimbus cloud of a typical cyclone, and is usually the last cloud observed immediately before, and the first cloud seen immediately after, long-continued precipitation. When observed just before sunset it has a fire-red appearance, which is replaced by an ashen gray color shortly after the sun has sunk below the horizon.

TABLE 6.—*Weather conditions following strato-cumulus clouds.*

Clouds moved from—	Number of cases.	Precipitation followed.		Temperature changed within 24 hours.		
		Within 24 hours.	Within 36 hours.	Less than 4°.	4° or more warmer.	4° or more colder.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
N.	11	18	27	82	18	0
NE.	5	40	60	40	60	0
E.	2					
SE.	13	69	100	69	31	0
S.	29	86	90	66	14	20
SW.	46	83	87	74	9	17
W.	74	39	65	73	19	8
NW.	34	32	47	71	21	8
Calm.	9	67	89	34	33	33

Table 6 is a summary of the weather conditions following the observation of 223 cases of strato-cumulus clouds at San Francisco. Again it is evident that the winds are prevailingly west. The significance of strato-cumulus clouds in regard to precipitation is unmistakable. With the exception of those moving from the north or the northwest, clouds of this type are followed by precipitation within 36 hours by far the greater part of the time. Of the 13 cases of those moving from the southeast, every one was followed by precipitation within 36 hours, while of the 29 instances of those moving from the south, 90 per cent were so followed. Though not indicated in the table, the rainfall was usually heavy when the clouds were observed to move from a southerly point.

As far as temperature changes are concerned, strato-cumulus clouds also have considerable significance. Varying with the direction of movement, 18 to 66 per cent of these clouds were followed by temperature changes within 24 hours. These changes were prevailingly positive for clouds moving from any direction except south or southwest, for which directions the changes were more often negative.

SUMMARY AND CONCLUSIONS.

Everywhere within the United States, and particularly along the Pacific coast, clouds offer the forecaster a clue to the coming weather which can not well be disregarded. Considered without respect to their direction of movement, or without relation to the other phenomena usually associated with cyclones, their significance is slight. When considered with respect to the direction from which they move, together with their relation to the more significant fact of pressure changes, they assist the forecaster to determine the relative position of the cyclone center. Clouds should enable observers to give their respective district forecasters valuable information, as well as to aid local officials in amplifying the district forecast. In the sequence of weather changes experienced with the passage of a typical cyclone, clouds aid one in establishing the stages in the series of events.

One of the principles of forecasting recognizes the fact that converging winds tend to produce precipitation, while diverging winds tend to produce clearing weather. (The former process causes ascending currents, while the latter results in descending air.) Since the wind data included in the reports of the regular observations are those at the moment of observation only, they sometimes refer to a temporary or a local condition. The movements of the clouds, being determined by the free air, are not subject to temporary fluctuations or to local peculiarities. When cloud observations are plotted, together with the other observations, on the forecast map, the relation between their movements and the barometric distribution is readily apparent under marked cyclonic control. The amount of cloud observed at any one station is of importance only in so far as it shows the local extent of the cloud-forming conditions, the greater the amount of cloud the more wide-spread the conditions which produce it, and vice versa.

In a region of uneven topography surface winds are deceptive, both in regard to direction and to velocity. Cloud observations present a means of determining the true barometric vector in such a region. From a study of almost a thousand cloud observations made at San Francisco during nine years it is apparent that the significance of clouds regarding subsequent precipitation is worthy of the forecaster's attention, the significance increasing as the height of the cloud decreases. The significance regarding precipitation varies greatly with direction at all cloud levels. For the highest clouds those moving from the southwest are most frequently followed by rain; for those of intermediate levels those from the south are so followed; while for the lowest clouds southeast is the direction of greatest significance, the probability of rain increasing as the direction changes from southwest to southeast, and the height of the cloud diminishes.

As far as temperature changes are concerned, the significance of clouds is not great at San Francisco. It is least with high clouds and greatest with low clouds, and varies greatly with direction at all levels. This fact is doubtless influenced by the semimarine environment of the city.

DISCUSSION.

Before the establishment of weather services and the systematic forecasting of the weather from synoptic charts and based upon scientific principles, clouds undoubtedly formed the best and most popular index of approaching weather conditions. They are referred to from the earliest history as premonitions of the approach of storms, and were carefully watched and studied by mariners and others to whom the future weather was of vital importance; and certain well recognized kinds of clouds were the best known index of an approaching storm.

In more recent years, with our increased knowledge of meteorology, clouds have been systematically studied and classified, and their value to the forecaster is no longer an open question. Certain kinds of clouds are almost invariably associated with certain kinds of weather, and at times when the distribution of barometric pressure and temperature and wind velocities and directions are such as to create doubt in the mind of the forecaster, the kind and amount of clouds, and the direction in which they are moving, will help him to decide upon the proper forecast to issue.

The value of the kind, amount, and direction of the clouds to the forecaster on the Pacific coast can not be overestimated. Many times the approach of a storm from the ocean is indicated by the cloud formation several hours before the pressure begins to fall or the winds change in direction and increase in force. Some of the best forecasting that I have ever seen was largely based upon the character and movement of the clouds.

In the forecasts issued from this office for the benefit of the raisin growers when drying their crop in the late summer and early fall, the value of cloud formation is pre-eminent. The conditions to be guarded against are those of unsettled weather, when scattered showers occur in the mountains and foothills and extend down into the valley. There are several types of maps which indicate these conditions, but they are not likely to produce rain unless preceded or accompanied by the rapid formation of a cumulus cap, first appearing on the eastern slope of the Sierra and later extending over the range to the San Joaquin Valley side.—*G. H. Willson, District Forecaster.*

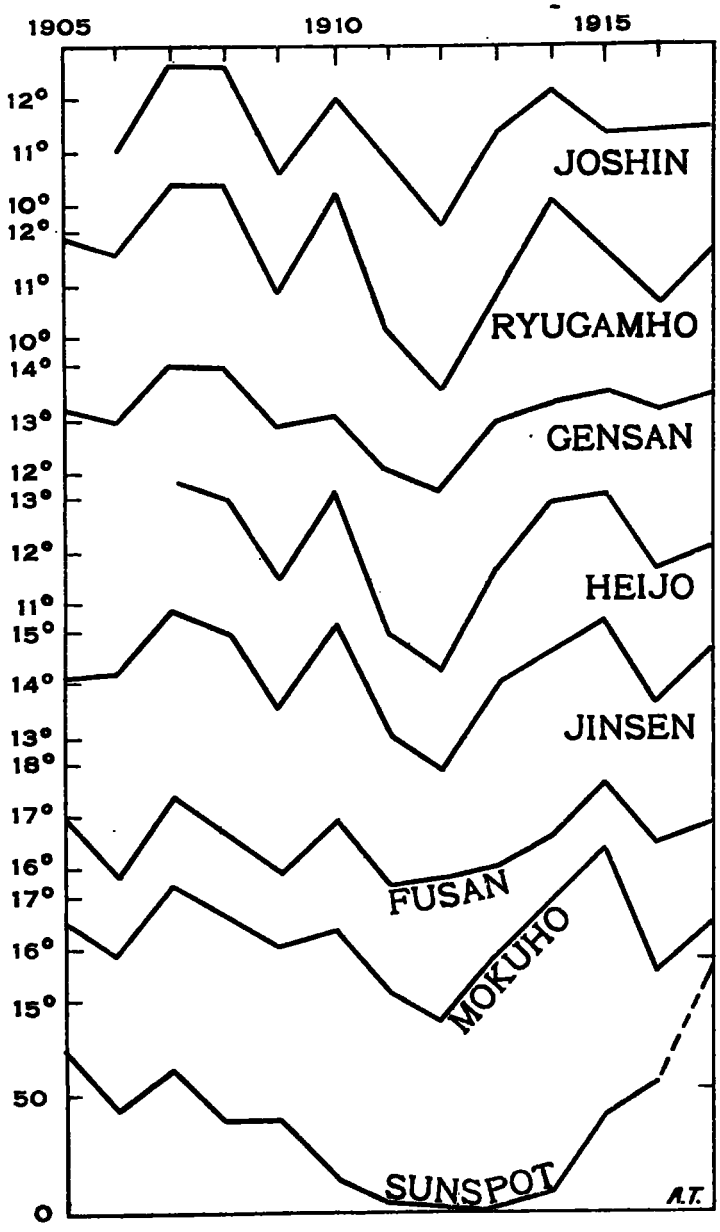

FIG. 1.—Sun-spot numbers, and October temperatures in Chosen.

SOME CORRELATIONS BETWEEN SOLAR ACTIVITY AND THE CLIMATE OF THE FAR EAST.[1]

By R. SEKIGUCHI.

1. *Solar activity and October temperatures of some parts of Chosen (Korea).*—In this report we intend to show the existence of correlations between annual sun-spot numbers and October temperatures of various parts of Chosen. A glance at figure 1 shows undeniable similarities between the general run of the curves representing variations of temperature and the curve of annual sun-spot numbers, though there are many dissimilarities if they are compared part by part. The correlation coefficients have been calculated with the following results:

		Probable error.
Ryugamho (Yongampo)	+0.39	±0.158
Gensan (Wonsan)	+0.58	±0.124
Jinsen (Chemulpo)	+0.39	±0.158
Fusan	+0.48	±0.143
Mokuho (Moppo)	+0.44	±0.150

Similar relations seem to exist throughout the wide area including not only the whole of Chosen but also the northern part of China and the eastern part of Siberia. (See fig. 2.) For instance, the correlation coefficient for Irkutsk (1886–1904) is $+0.41 \pm 0.132$, and that for Tsingtau (1898–1915, except 1914) $+0.43 \pm 0.123$.

In Chosen and Manchuria the month of October is one of the quietest seasons of the year; hence the mean temperature of that month in these regions may be consid-

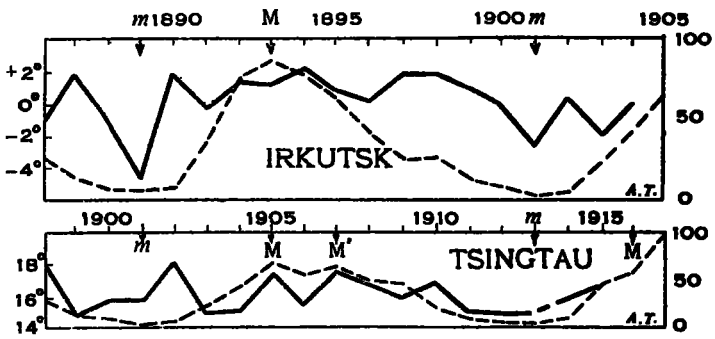

FIG. 2.—Sun-spot numbers, and October temperatures.

(Broken line=relative annual sun-spot numbers, has been supplied by the editor.)

ered to follow faithfully the general distribution of barometric pressure in the Far East, without being greatly disturbed by passing cyclones, etc., as is generally the case in the other seasons and in most parts of Japan proper. Although it may be somewhat premature to draw conclusions from the results that have been found from the observations of such a short period, we have grounds for assuming that they have the following significance: *There is a marked difference between the progress of the development of the Siberian* HIGH *in the period of sun-spot maximum and in the period of sun-spot minimum.* More definite conclusions will be obtained if correlation coefficients over more extended areas be examined. The necessary computations are now going on, and the results will be reported later.

2. *Solar activity and rainfall.*—Some statistical researches have been made to see if there be any correlation between the annual rainfall of Seoul, Chosen, and the annual sun-spot numbers. The rainfall data for the period before 1907 were taken from the table compiled by the late Dr. Y. Wada from the records of the Royal

[1] Condensed from abstract in Jour. Met'l Soc. Japan, Tokyo, July, 1918, 37:33–42.